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The Fourth and Fifth Spectra of Vanadium (V IV and V V)

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The V IV spectrum has been extended by using as light sources a condensed spark and a hollow cathode discharge. With the new data, the experimental interpretation of levels of the $3d^2$, $3d\,4d$, $3d\,5s$, $3d\,5p$, $3d\,4f$, $3d\,5d$ and $3d\,6s$ configurations has been completed with the exception of three levels of the $3d\,4f$ and $3d\,5d$ configurations. Four levels of the $3d\,5g$ electron configuration have also been found. These levels account for 340 of the 360 lines assigned to V IV in the region 675 Å–5940 Å.

Three members of the $3d\,ns$ series give an ionization potential of 376730 ± 40 cm$^{-1} = 46.70$ volts.

The $4d\,^2$D term of V V has also been located in the course of this work. With the aid of the new observations between 675 Å and 2200 Å the value of some levels already known has been improved.

Key Words: Atomic spectra, V IV and V V; classified lines, V IV and V V spectra; spectra, V IV and V V; terms, V IV and V V spectra; vanadium, the fourth and fifth spectra of.

1. Introduction

The fourth spectrum of vanadium was analyzed by White [1][1] in 1929, who found the terms of the main configurations, $3d^2$, $3d\,4s$, $3d\,4p$, and two terms of the $3d\,4d$ configuration. From a study of related spectra, B. Edlén deduced (see A.E.L. [2]), that the singlet term ^{1}S of the $3d^2$ configuration was incorrect and that the energy level values of all singlet terms should be decreased by 698 cm^{-1}.

As a result of new observations a complete revision and extension of the V IV spectrum has been made, and the results are presented in this paper, together with some new levels of V V.

2. Experimental Details

The analyses are based on two sets of spectrograms. The first set was obtained by the author during a stay at Princeton University, and covers the region 675 to 2200 Å. The plates were taken with the 2 meter-grating spectrograph at Palmer Physical Laboratory, by using as light source a condensed spark in helium, under the same conditions used by A. G. Shenstone to excite Ni III [3]. In the present case V I, V II, V III, V IV and V V were excited; by observation of the polarity of the lines it was not difficult to differentiate among the lines corresponding to the various stages of ionization. (See fig. 1.)

The second set of plates, from 2200 to 5940 Å, was obtained by Velasco in Lund in 1953. The light source was a pulsed hollow cathode discharge used under the conditions described in a paper on V III [4]; the spectral instruments used were a 21-ft grating spectrograph in a Wadsworth mounting and a quartz prism spectrograph Hilger–E478. More than one thousand lines were then attributed to V III but it was pointed out that some of them might belong to V IV. In most of the grating spectrograms, it was impossible to distinguish V III from V IV lines. Other spectrograms obtained with the prism spectrograph permitted, however, an unambiguous distinction between V III and V IV lines. The analysis of V IV could thus be substantially extended.

On the vacuum spectrograph the plate factor was about 4.2 Å/mm in the first order. From 675 to 800 Å all but the weakest lines were measured in the second order. In the hollow cathode spectrograms the plate factor varied from 2.0 Å/mm in the prism spectrograms to about 5 Å/mm in those taken in the first order.

Most of the wavelength values given in table 3 are averages of measurements made on two or more plates. To distinguish between the accuracy of different measurements three decimal places have been retained for the lines with an estimated probable error not higher than ± 0.01 Å. When only two decimal places are given in the wavelength, the error may range from 0.01 to 0.03 Å, depending on the character of the line. Correspondingly the number of significant figures in the wave number column (table 3) has been adjusted to the assumed accuracy of the wavelengths. The symbols used in the "Intensity" column in table 3 are those recommended by the Joint Commission for Spectroscopy [5].

About 360 lines in all were assigned to V IV.

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[1] Figures in brackets indicate the literature references at the end of this paper.

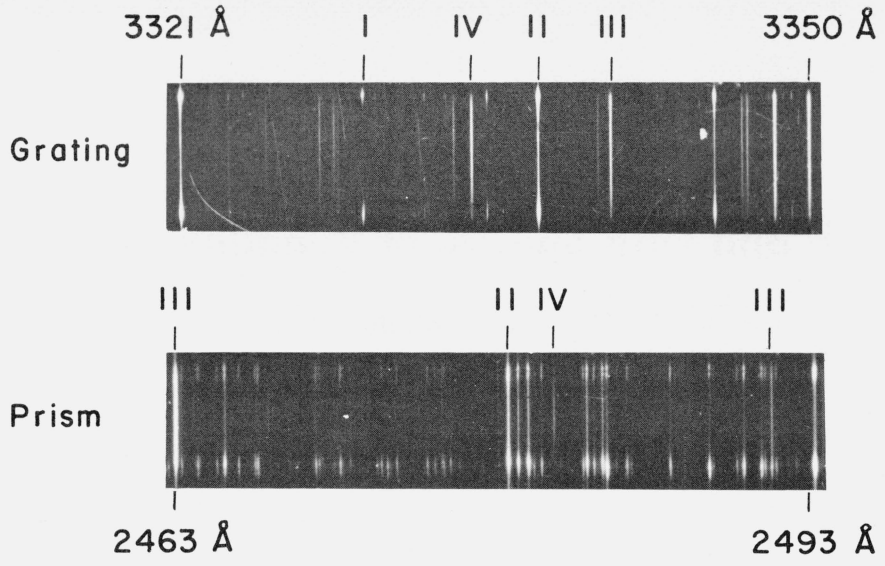

FIGURE 1. *Hollow Cathode Spectra of Vanadium. The lines belonging to each spectrum are indicated by the corresponding roman numeral.*

On the prism spectrum V IV lines are clearly shorter and wider than V III lines of similar intensity.

3. Analysis

Within the main configurations only the term $3d^2\ ^1S$ was missing. The only remaining unclassified line in the region of the $3d^2$–$3d\,4p$ transitions, $\lambda = 884.146$ Å, was, therefore, designated as the ^1S–$^1P^\circ$ combination, giving a value of 42462.1 cm^{-1} for the ^1S level. New transitions between the even and odd levels confirm the reality of the energy levels given in A.E.L. [2], with exception of the $3d(^2D)4d\ ^3F$ term.

With the present observations the values of the energy levels already known have been improved. An asterisk in tables 1 and 2 indicates that a slight change in the level value has been made as a result of this revision.

The determination of levels and their grouping into terms in the higher configurations did not offer special difficulties. The search for new energy levels has been made by the usual method of recurring differences. The assignment of levels to terms and electron configurations, takes into account the relative intensities of lines in multiplets, the intervals, and the relative positions of terms and configurations deduced from comparisons with such related spectra as Ti III and Ti IV. In the case of the $4f$ electron configuration the theoretical calculations for Fe VII by Y. Shadmi were used as a guide [6].

The limit of the $3d\,nx$ configurations being a ^2D term of V V and the coupling nearly *LS* for low values of "x", the designation of the levels was rather straightforward. In the case of the $4f$ electron configuration there are a few levels that share the same *LS* character. The designation is, therefore, not so conclusive, and the assignment has been made by comparison with Ti III [7] and Fe VII [8, 6], as stated above. The $3d\,5g$ configuration is expected to show a high percentage of pair coupling. Only four levels have been found with certainty, which, accordingly, are presented in table 1 with pair-coupling notation.

As a result of this analysis, all the terms belonging to $3d\ 4d$, $3d\ 5s$, $3d\ 5p$, $3d\ 4f$, $3d\ 5d$ and $3d\ 6s$ have been found with the exception of three levels of the $3d\,4f$ and $3d\,5d$ configurations (tables 1 and 2). The total number of classified lines has now been extended to 340 lines of the V IV spectrum. Their wavelengths, visual intensities, wave numbers and classifications are given in table 3. Only twenty of the observed lines still remain unclassified, and very probably they correspond to $4f-5g$ transitions.

Ionization Potential.—By using a Ritz formula $n^* = n + a + bT$ on the three observed members of the $3d(^2D)ns$ series an ionization potential of 376730 ± 40 cm^{-1} or 46.70 volts has been calculated. The levels and series used for the calculations of this limit are collected in table 4.

TABLE 1. *Even levels of* V IV

Config.	Desig.	J	Level	Interval
$3d^2$	$3d\,^3F$	2	0.0*	
				325.4
		3	325.4*	
				409.3
		4	734.7*	
$3d^2$	$3d\,^1D$	2	10959.3*	
$3d^2$	$3d\,^3P$	0	13122.8*	
				116.4
		1	13239.2*	
				219.1
		2	13458.3*	
$3d^2$	$3d\,^1G$	4	18391.2*	
$3d^2$	$3d\,^1S$	0	42462.1	
$3d(^2D)4s$	$4s\,^3D$	1	96196.1*	
				216.0
		2	96412.1*	
				385.7
		3	96798.0*	
$3d(^2D)4s$	$4s\,^1D$	2	100200.7*	
$3d(^2D)4d$	$4d\,^1F$	3	215957.7	
$3d(^2D)4d$	$4d\,^3D$	1	216905.0	
				203.0
		2	217108.0	
				242.0
		3	217350.0	
$3d(^2D)4d$	$4d\,^3G$	3	217836.3*	
				263.7
		4	218100.0*	
				363.6
		5	218463.6*	
$3d(^2D)4d$	$4d\,^1P$	1	217990.7	
$3d(^2D)4d$	$4d\,^3S$	1	220343.5	

TABLE 1. *Even levels of* V IV—Continued

Config.	Desig.	J	Level	Interval
$3d(^2D)4d$	$4d\ ^3F$	2	222794.6	
				238.4
		3	223033.0	
				271.6
		4	223304.6	
$3d(^2D)4d$	$4d\ ^1D$	2	225804.1	
$3d(^2D)4d$	$4d\ ^3P$	0	226521.6	
				95.5
		1	226617.1	
				179.2
		2	226796.3	
$3d(^2D)4d$	$4d\ ^1G$	4	227712.5	
$3d(^2D)4d$	$4d\ ^1S$	0	234121.8	
$3d(^2D)5s$	$5s\ ^3D$	1	236148.6	
				173.8
		2	236322.4	
				444.5
		3	236766.9	
$3d(^2D)5s$	$5s\ ^1D$	2	237638.8	
$3d(^2D)5d$	$5d\ ^1F$	3	283459.4	
$3d(^2D)5d$	$5d\ ^3D$	1	283722.7	
				217.7
		2	283940.4	
				286.3
		3	284226.7	
$3d(^2D)5d$	$5d\ ^3G$	3	284101.1	
				239.0
		4	284340.1	
				359.2
		5	284699.3	
$3d(^2D)5d$	$5d\ ^1P$	1	284365.7?	
$3d(^2D)5d$	$5d\ ^3S$	1	285298.6	
$3d(^2D)5d$	$5d\ ^3F$	2	285798.9	
				258.0
		3	286056.9	
				229.6
		4	286286.5	

TABLE 1. *Even levels of* V IV—Continued

Config.	Desig.	J	Level	Interval
$3d(^2D)5d$	$5d\ ^1D$	2	287221.4	
$3d(^2D)5d$	$5d\ ^3P$	2	287733.4	
$3d(^2D)5d$	$5d\ ^1G$	4	288127.6	
$3d(^2D)6s$	$6s\ ^3D$	1	291796.0	
				122.1
		2	291918.1	
				499.5
		3	292417.6	
$3d(^2D)6s$	$6s\ ^1D$	2	292766.7	
$3d(^2D)5g$	$5g\ [3\frac{1}{2}]$	3	306323.1	
				4.6
		4	306327.7	
$3d(^2D)5g$	$5g\ [4\frac{1}{2}]$	5	306871.0	
				−5.3
		4	306876.3	

TABLE 2. *Odd levels of* V IV

Config.	Desig.	J	Level	Interval
$3d(^2D)4p$	$4p\ ^1D°$	2	*144273.1**	
$3d(^2D)4p$	$4p\ ^3D°$	1	*146117.7**	
				311.6
		2	*146429.3**	
				425.8
		3	*146855.1**	
$3d(^2D)4p$	$4p\ ^3F°$	2	*147135.2**	
				521.3
		3	*147656.5**	
				712.7
		4	*148369.2**	
$3d(^2D)4p$	$4p\ ^3P°$	0	*151449.1**	
				−22.1
		1	*151427.0**	
				140.3
		2	*151567.3**	

Table 2. *Odd levels of* V IV—Continued

Config.	Desig.	J	Level	Interval
$3d(^2D)4p$	$4p\ ^1F°$	3	*153918.7**	
$3d(^2D)4p$	$4p\ ^1P°$	1	*155565.5**	
$3d(^2D)5p$	$5p\ ^1D°$	2	*254468.8*	
$3d(^2D)5p$	$5p\ ^3D°$	1	*254824.1*	
				322.7
		2	*255146.8*	
				298.7
		3	*255445.5*	
$3d(^2D)5p$	$5p\ ^3F°$	2	*255463.3*	
				284.3
		3	*255747.6*	
				504.1
		4	*256251.7*	
$3d(^2D)5p$	$5p\ ^3P°$	0	*256739.9*	
				41.9
		1	*256781.8*	
				361.4
		2	*257143.2*	
$3d(^2D)5p$	$5p\ ^1F°$	3	*257690.8*	
$3d(^2D)5p$	$5p\ ^1P°$	1	*258288.8*	
$3d(^2D)4f$	$4f\ ^1G°$	4	*263111.4*	
$3d(^2D)4f$	$4f\ ^3F°$	2	*263593.0*	
				15.3
		3	*263608.3*	
				504.8
		4	*264113.1*	
$3d(^2D)4f$	$4f\ ^3H°$	4	*263822.4*	
				339.4
		5	*264161.8*	
				683.9
		6	*264845.7*	
$3d(^2D)4f$	$4f\ ^3G°$	3	*263902.3*	
				499.6
		4	*264401.9*	
				190.0
		5	*264591.9*	

Table 2. *Odd levels of* V IV—Continued

Config.	Desig.	J	Level	Interval
$3d(^2D)4f$	$4f\ ^1D^\circ$	2	*264482.8*	
$3d(^2D)4f$	$4f\ ^1F^\circ$	3	*264902.2*	
$3d(^2D)4f$	$4f\ ^3D^\circ$	1	*265019.7*	47.7
		2	*265067.4*	204.2
		3	*265271.6*	
$3d(^2D)4f$	$4f\ ^3P^\circ$	1, 2	*265879.2*	
$3d(^2D)4f$	$4f\ ^1H^\circ$	5	*266600.3*	

TABLE 3. *Classified lines of* V IV

λ vac.	Intensity	Wave number	Classification	λ vac.	Intensity	Wave number	Classification
675.469	30	148045.2	$3d\ ^3F_3-4p\ ^3F^\circ_4$	722.912	40	138329.4	$3d\ ^3P_1-4p\ ^3P^\circ_2$
677.345	200	147635.2	$3d\ ^3F_4-4p\ ^3F^\circ_4$	723.045	40	138303.9	$3d\ ^3P_0-4p\ ^3P^\circ_1$
678.740	60	147331.8	$3d\ ^3F_3-4p\ ^3F^\circ_3$	723.537	40	138209.9	$3d\ ^3P_1-4p\ ^3P^\circ_0$
679.647	50	147135.2	$3d\ ^3F_2-4p\ ^3F^\circ_2$	723.652	40	138188.0	$3d\ ^3P_1-4p\ ^3P^\circ_1$
680.632	40	146922.2	$3d\ ^3F_4-4p\ ^3F^\circ_3$	724.068	40	138108.5	$3d\ ^3P_2-4p\ ^3P^\circ_2$
681.145	40	146811.6	$3d\ ^3F_3-4p\ ^3F^\circ_2$	724.809	5	137967.3	$3d\ ^3P_2-4p\ ^3P^\circ_1$
682.455	40	146529.8	$3d\ ^3F_3-4p\ ^3D^\circ_3$	734.344	20	136175.9	$3d\ ^1D_2-4p\ ^3F^\circ_2$
682.923	40	146429.3	$3d\ ^3F_2-4p\ ^3D^\circ_2$	737.854	400	135528.1	$3d\ ^1G_4-4p\ ^1F^\circ_3$
684.368	500	146120.2	$3d\ ^3F_4-4p\ ^3D^\circ_3$ $3d\ ^3F_2-4p\ ^3D^\circ_1$	745.165	20	134198.4	$3d\ ^3P_2-4p\ ^3F^\circ_3$
				749.641	40	133397.1	$3d\ ^3P_2-4p\ ^3D^\circ_3$
684.450	100	146102.7	$3d\ ^3F_3-4p\ ^3D^\circ_2$	750.110	150	133313.7	$3d\ ^1D_2-4p\ ^1D^\circ_2$
691.530	100	144606.8	$3d\ ^1D_1-4p\ ^1P^\circ_1$	750.809	40	133189.6	$3d\ ^3P_1-4p\ ^3D^\circ_2$
693.128	50	144273.4	$3d\ ^3F_2-4p\ ^1D^\circ_2$	751.908	30	132995.0	$3d\ ^3P_0-4p\ ^3D^\circ_1$
699.497	30	142959.8	$3d\ ^1D_2-4p\ ^1F^\circ_3$	752.038	30	132972.0	$3d\ ^3P_2-4p\ ^3D^\circ_2$
702.035	1	142443.0	$3d\ ^3P_0-4p\ ^1P^\circ_1$	752.568	20	132878.3	$3d\ ^3P_1-4p\ ^3D^\circ_1$
711.911	20	140467.0	$3d\ ^1D_2-4p\ ^3P^\circ_1$	778.433	tr	128463.2	$3d\ ^1G_4-4p\ ^3D^\circ_3$

TABLE 3. *Classified lines of* V IV—Continued

λ vac.	Intensity	Wave number	Classification	λ vac.	Intensity	Wave number	Classification
884.146	30	113103.4	$3d\ ^1S_0-4p\ ^1P^\circ_1$	1326.807	5	75368.9	$4p\ ^3P^\circ_1-4d\ ^3P_2$
1071.054	20	93366.0	$4p\ ^1D^\circ_2-5s\ ^1D_2$	1329.288	10	75228.2	$4p\ ^3P^\circ_2-4d\ ^3P_2$
1086.382	5	92048.6	$4p\ ^1D^\circ_2-5s\ ^3D_2$	1329.968	10	75189.8	$4p\ ^3P^\circ_1-4d\ ^3P_1$
1096.375	2	91209.7	$4p\ ^3D^\circ_2-5s\ ^1D_2$	1330.355	10	75167.9	$4p\ ^3P^\circ_0-4d\ ^3P_1$
1110.720	2	90031.7	$4p\ ^3D^\circ_1-5s\ ^3D_1$	1331.665	tr	75094.0	$4p\ ^3P^\circ_1-4d\ ^3P_0$
1112.199	5	89912.0	$4p\ ^3D^\circ_3-5s\ ^3D_3$	1332.459	3	75049.2	$4p\ ^3P^\circ_2-4d\ ^3P_1$
1112.436	5	89892.8	$4p\ ^3D^\circ_2-5s\ ^3D_2$	1334.493	( )	74934.8	$4p\ ^3F^\circ_4-4d\ ^3F_4$
1127.836	20	88665.4	$4p\ ^3F^\circ_3-5s\ ^3D_2$	1339.335	5	74663.9	$4p\ ^3F^\circ_4-4d\ ^3F_3$
1131.255	20	88397.4	$4p\ ^3F^\circ_4-5s\ ^3D_3$	1344.493	tr	74377.5	$4p\ ^3P^\circ_1-4d\ ^1D_2$
1194.462	20	83719.7	$4p\ ^1F^\circ_3-5s\ ^1D_2$	1347.030	1	74237.4	$4p\ ^3P^\circ_2-4d\ ^1D_2$
1226.523	60	81531.3	$4p\ ^1D^\circ_2-4d\ ^1D_2$	1355.131	80	73793.6	$4p\ ^1F^\circ_3-4d\ ^1G_4$
1242.248	3	80499.2	$4p\ ^3D^\circ_1-4d\ ^3P_1$	1356.529	10	73717.6	$4p\ ^1D^\circ_2-4d\ ^1P_1$
1243.718	10	80404.1	$4p\ ^3D^\circ_1-4d\ ^3P_0$	1391.105	20	71885.3	$4p\ ^1F^\circ_3-4d\ ^1D_2$
1244.287	2	80367.3	$4p\ ^3D^\circ_2-4d\ ^3P_2$	1395.001	60	71684.5	$4p\ ^1D^\circ_2-4d\ ^1F_3$
1247.069	30	80188.0	$4p\ ^3D^\circ_2-4d\ ^3P_1$	1400.416	5	71407.3	$4p\ ^3D^\circ_2-4d\ ^3G_3$
1250.918	20	79941.3	$4p\ ^3D^\circ_3-4d\ ^3P_2$	1403.618	8	71244.4	$4p\ ^3D^\circ_3-4d\ ^3G_4$
1271.153	2	78668.7	$4p\ ^3F^\circ_2-4d\ ^1D_2$	1408.639	8	70990.5	$4p\ ^3D^\circ_1-4d\ ^3D_2$
1272.972	30	78556.3	$4p\ ^1P^\circ_1-4d\ ^1S_0$	1410.018	8	70921.1	$4p\ ^3D^\circ_3-4d\ ^3D_2$
1273.529	10	78522.0	$4p\ ^1D^\circ_2-4d\ ^3F_2$	1412.686	20	70787.1	$4p\ ^3D^\circ_1-4d\ ^3D_1$
1304.173	30	76676.9	$4p\ ^3D^\circ_1-4d\ ^3F_2$	1414.409	50	70700.9	$4p\ ^3F^\circ_2-4d\ ^3G_3$
1305.420	40	76603.7	$4p\ ^3D^\circ_2-4d\ ^3F_3$	1414.842	20	70679.3	$4p\ ^3D^\circ_2-4d\ ^3D_2$
1308.061	50	76449.0	$4p\ ^3D^\circ_3-4d\ ^3F_4$	1418.533	30	70495.4	$4p\ ^3D^\circ_3-4d\ ^3D_3$
1309.502	10	76364.9	$4p\ ^3D^\circ_2-4d\ ^3F_2$	1418.921	10	70476.1	$4p\ ^3D^\circ_2-4d\ ^3D_1$
1312.717	20	76177.9	$4p\ ^3D^\circ_3-4d\ ^3F_3$	1419.580	80	70443.4	$4p\ ^3F^\circ_3-4d\ ^3G_4$
1317.566	5	75897.5	$4p\ ^3F^\circ_2-4d\ ^3F_3$	1423.420	10	70253.3	$4p\ ^3D^\circ_3-4d\ ^3D_2$
1321.719	10	75659.0	$4p\ ^3F^\circ_2-4d\ ^3F_2$	1423.719	30	70238.6	$4p\ ^1P^\circ_1-4d\ ^1D_2$
1321.917	10	75647.7	$4p\ ^3F^\circ_3-4d\ ^3F_4$	1424.197	tr	70215.0	$4p\ ^3F^\circ_2-4d\ ^3D_3$
1326.666	5	75376.9	$4p\ ^3F^\circ_3-4d\ ^3F_3$	1424.916	10	70179.4	$4p\ ^3F^\circ_3-4d\ ^3G_3$

TABLE 3. *Classified lines of* V IV—Continued

λ vac.	Intensity	Wave number	Classification	λ vac.	Intensity	Wave number	Classification
1426.654	100	70094.1	$4p\ ^3F^\circ_4-4d\ ^3G_5$	1963.103	300	50939.8	$4s\ ^3D_1-4p\ ^3F^\circ_2$
1429.114	10	69973.4	$4p\ ^3F^\circ_2-4d\ ^3D_2$	1966.244	20	50858.4	$4s\ ^3D_3-4p\ ^3F^\circ_3$
1433.276	1	69770.2	$4p\ ^3F^\circ_2-4d\ ^3D_1$	1971.471	40	50723.5	$4s\ ^3D_2-4p\ ^3F^\circ_2$
1434.092	15	69730.5	$4p\ ^3F^\circ_4-4d\ ^3G_4$	1982.422	15	50443.3	$4s\ ^3D_2-4p\ ^3D^\circ_3$
1434.842	15	69694.1	$4p\ ^3F^\circ_3-4d\ ^3D_3$	1990.712	40	50233.3	$4s\ ^3D_1-4p\ ^3D^\circ_2$
1439.834	1	69452.5	$4p\ ^3F^\circ_3-4d\ ^3D_2$	1997.722	500	50057.0	$4s\ ^3D_3-4p\ ^3D^\circ_3$
1447.120	tr	69102.8	$4p\ ^3D^\circ_3-4d\ ^1F_3$	1999.320	200	50017.0	$4s\ ^3D_2-4p\ ^3D^\circ_2$
1449.681	20	68980.7	$4p\ ^3F^\circ_4-4d\ ^3D_3$	λ air			
1451.042	30	68916.0	$4p\ ^3P^\circ_1-4d\ ^3S_1$	2002.480	100	49921.9	$4s\ ^3D_1-4p\ ^3D^\circ_1$
1451.496	10	68894.5	$4p\ ^3P^\circ_0-4d\ ^3S_1$	2011.180	40	49706.0	$4s\ ^3D_2-4p\ ^3D^\circ_1$
1454.000	40	68775.8	$4p\ ^3P^\circ_2-4d\ ^3S_1$	2014.199	40	49631.5	$4s\ ^3D_3-4p\ ^3D^\circ_2$
1520.142	60	65783.3	$4p\ ^3P^\circ_2-4d\ ^3D_3$	2027.144	1	49314.6	$4d\ ^1F_3-4f\ ^3D^\circ_3$
1522.493	40	65681.7	$4p\ ^3P^\circ_1-4d\ ^3D_2$	2042.454	20 *H*	48945.0	$4d\ ^1F_3-4f\ ^1F^\circ_3$
1525.756	10	65541.3	$4p\ ^3P^\circ_2-4d\ ^3D_2$	2060.113	tr *H*	48525.5	$4d\ ^1F_3-4f\ ^1D^\circ_2$
1527.223	15	65478.3	$4p\ ^3P^\circ_1-4d\ ^3D_1$	2063.563	2 *H*	48444.4	$4d\ ^1F_3-4f\ ^3G^\circ_4$
1527.721	15	65457.0	$4p\ ^3P^\circ_0-4d\ ^3D_1$	2079.300	30	48077.8	$4s\ ^3D_1-4p\ ^1D^\circ_2$
1601.915	80	62425.3	$4p\ ^1P^\circ_1-4d\ ^1P_1$	2084.433	20 *H*	47959.4	$4d\ ^3D_2-4f\ ^3D^\circ_2$
1611.879	80	62039.4	$4p\ ^1F^\circ_3-4d\ ^1F_3$	2086.073	30 *H*	47921.7	$4d\ ^3D_3-4f\ ^3D^\circ_3$
1806.184	80	55365.3	$4s\ ^1D_1-4p\ ^1P^\circ_1$	2088.737	50 *h*	47860.6	$4s\ ^3D_2-4p\ ^1D^\circ_2$
1809.854	60	55253.1	$4s\ ^3D_1-4p\ ^3P^\circ_0$	2105.709	tr	47474.9	$4s\ ^3D_3-4p\ ^1D^\circ_2$
1810.566	30	55231.3	$4s\ ^3D_1-4p\ ^3P^\circ_1$	2106.560	2	47455.7	$4s\ ^1D_2-4p\ ^3F^\circ_3$
1813.050	50	55155.7	$4s\ ^3D_2-4p\ ^3P^\circ_2$	2120.052	40 *H*	47153.7	$4d\ ^1F_3-4f\ ^1G^\circ_4$
1817.676	100	55015.3	$4s\ ^3D_2-4p\ ^3P^\circ_1$	2129.934	30	46935.0	$4s\ ^1D_2-4p\ ^3F^\circ_2$
1825.836	200	54769.4	$4s\ ^3D_3-4p\ ^3P^\circ_2$	2136.330	10 *h*	46794.5	$4d\ ^3D_2-4f\ ^3G^\circ_3$
1861.558	300	53718.4	$4s\ ^1D_2-4p\ ^1F^\circ_3$	2137.741	20 *h*	46763.6	$4d\ ^3D_3-4f\ ^3F^\circ_4$
1939.065	500	51571.2	$4s\ ^3D_3-4p\ ^3F^\circ_4$	2141.199	40 *H*	46688.1	$4d\ ^3D_1-4f\ ^3F^\circ_2$
1946.772	5	51367.1	$4s\ ^1D_2-4p\ ^3P^\circ_2$	2146.828	50 *H*	46565.7	$4d\ ^3G_3-4f\ ^3G^\circ_4$
1951.432	400	51244.4	$4s\ ^3D_2-4p\ ^3F^\circ_3$	2149.852	20 *H*	46500.2	$4d\ ^3D_2-4f\ ^3F^\circ_3$

TABLE 3. *Classified lines of* V IV—Continued

λ air	Intensity	Wave number	Classification
2150.231	40 *H*	46492.0	$4d\,^3G_4-4f\,^3G^\circ_5$ $4d\,^1P_1-4f\,^1D^\circ_2$
2151.087	20 *h*	46473.5	$4d\,^3D_3-4f\,^3H^\circ_4$
2155.336	100 *H*	46381.9	$4d\,^3G_5-4f\,^3H^\circ_6$
2159.055	10 *H*	46302.0	$4d\,^3G_4-4f\,^3G^\circ_4$
2160.222	20 *H*	46277.0	$4d\,^3G_3-4f\,^3F^\circ_4$
2162.498	30	46228.3	$4s\,^1D_2-4p\,^3D^\circ_2$
2167.200	20 *H*	46128.0	$4d\,^3G_5-4f\,^3G^\circ_5$
2170.384	(40 *H*)	46060.4	$4d\,^3G_4-4f\,^3H^\circ_5$
2173.893	10 *H*	45986.0	$4d\,^3G_3-4f\,^3H^\circ_4$
2186.394	tr *H*	45723.1	$4d\,^3G_4-4f\,^3H^\circ_4$
2187.562	5 *H*	45698.7	$4d\,^3G_5-4f\,^3H^\circ_5$
2195.388	10 *H*	45535.8	$4d\,^3S_1-4f\,^3P^\circ_2$
2268.298	500	44072.3	$4s\,^1D_2-4p\,^1D^\circ_2$
2313.236	1 *H*	43216.2	$4f\,^1G^\circ_4-5g\,[3\tfrac{1}{2}]_4$
2321.962	1 *H*	43053.8	$4f\,^3H^\circ_4-5g\,[4\tfrac{1}{2}]_4$
2322.259	5 *H*	43048.3	$4f\,^3H^\circ_4-5g\,[4\tfrac{1}{2}]_5$
2326.291	3 *H*	42973.7	$4f\,^3G^\circ_3-5g\,[4\tfrac{1}{2}]_4$
2338.032	10 *H*	42757.9	$4f\,^3F^\circ_4-5g\,[4\tfrac{1}{2}]_5$
2339.548	20 *H*	42730.2	$4f\,^3F^\circ_2-5g\,[3\tfrac{1}{2}]_3$
2340.140	10 *H*	42719.4	$4f\,^3F^\circ_3-5g\,[3\tfrac{1}{2}]_4$
2340.704	5 *H*	42709.1	$4f\,^3H^\circ_5-5g\,[4\tfrac{1}{2}]_5$
2351.934	5 *H*	42505.2	$4f\,^3H^\circ_4-5g\,[3\tfrac{1}{2}]_4$
2353.639	3 *H*	42474.4	$4f\,^3G^\circ_4-5g\,[4\tfrac{1}{2}]_4$
2356.369	10 *H*	42425.2	$4f\,^3G^\circ_3-5g\,[3\tfrac{1}{2}]_4$
2356.624	5 *H*	42420.6	$4f\,^3G^\circ_3-5g\,[3\tfrac{1}{2}]_3$
2364.512	1 *H*	42279.1	$4f\,^3G^\circ_5-5g\,[4\tfrac{1}{2}]_5$
2378.290	1 *H*	42034.2	$4d\,^3F_3-4f\,^3D^\circ_2$
2381.712	10 *H*	41973.8	$4f\,^1F^\circ_3-5g\,[4\tfrac{1}{2}]_4$
2384.729	10 *H*	41920.7	$4f\,^3G^\circ_4-5g\,[3\tfrac{1}{2}]_3$
2387.663	3 *H*	41869.2	$4d\,^3F_3-4f\,^1F^\circ_3$
2395.450	10 *H*	41733.1	$4d\,^1F_3-5p\,^1F^\circ_3$
2402.855	5 *H*	41604.5	$4f\,^3D^\circ_3-5g\,[4\tfrac{1}{2}]_4$
2413.256	20 *H*	41425.2	$4f\,^3G^\circ_3-5g\,[3\tfrac{1}{2}]_4$
2413.524	5 *H*	41420.6	$4f\,^1F^\circ_3-5g\,[3\tfrac{1}{2}]_3$
2416.552	30 *h*	41368.7	$4d\,^3F_3-4f\,^3G^\circ_4$
2421.317	50 *h*	41287.3	$4d\,^3F_4-4f\,^3G^\circ_5$
2431.885	30 *h*	41107.9	$4d\,^3F_2-4f\,^3G^\circ_3$
2432.518	10 *h*	41097.2	$4d\,^3F_4-4f\,^3G^\circ_4$
2433.530	50 *h*	41080.1	$4d\,^3F_3-4f\,^3F^\circ_4$
2446.071	30 *h*	40869.5	$4d\,^3F_3-4f\,^3G^\circ_3$
2446.802	50 *h*	40857.3	$4d\,^3F_4-4f\,^3H^\circ_5$
2449.404	40 *h*	40813.9	$4d\,^3F_2-4f\,^3F^\circ_3$
2449.723	20 *h*	40808.6	$4d\,^3F_4-4f\,^3F^\circ_4$
2450.329	20 *h*	40798.5	$4d\,^3F_2-4f\,^3F^\circ_2$
2450.869	50 *h*	40789.5	$4d\,^3F_3-4f\,^3H^\circ_4$
2463.796	10 *h*	40575.5	$4d\,^3F_3-4f\,^3F^\circ_3$
2464.720	2 *h*	40560.3	$4d\,^3F_3-4f\,^3F^\circ_2$
2467.287	20 *h*	40518.1	$4d\,^3F_4-4f\,^3H^\circ_4$
2478.119	1 *H*	40341.0	$4d\,^3D_3-5p\,^1F^\circ_3$
2480.739	30 *h*	40298.4	$4d\,^1P_1-5p\,^1P^\circ_1$
2494.351	20 *h*	40078.5	$4d\,^3F_3-4f\,^1G^\circ_4$
2497.049	10 *h*	40035.2	$4d\,^3D_2-5p\,^3P^\circ_2$
2506.969	10 *h*	39876.8	$4d\,^3D_1-5p\,^3P^\circ_1$
2509.606	5 *h*	39834.9	$4d\,^3D_1-5p\,^3P^\circ_0$
2511.377	1 *H*	39806.8	$4d\,^3F_4-4f\,^1G^\circ_4$
2512.242	( )	39793.1	$4d\,^3D_3-5p\,^3P^\circ_2$

TABLE 3. *Classified lines of* V IV—Continued

λ air	Intensity	Wave number	Classification	λ air	Intensity	Wave number	Classification
2519.803	20 *h*	39673.7	$4d\,^3D_2-5p\,^3P^\circ_1$	2650.613	8 *h*	37715.9	$4d\,^3D_2-5p\,^3D^\circ_1$
2530.520	2 *h*	39505.7	$4d\,^1F_3-5p\,^3F^\circ_2$	2655.408	50 *H*	37647.8	$4d\,^3G_4-5p\,^3F^\circ_3$
2532.982	20 *h*	39467.3	$4d\,^1D_2-4f\,^3D^\circ_3$	2656.868	50 *H*	37627.1	$4d\,^3G_3-5p\,^3F^\circ_2$
2546.228	20 *h*	39262.0	$4d\,^3P_1-4f\,^3P^\circ_2$	2667.837	1 *h*	37472.4	$4d\,^1P_1-5p\,^3F^\circ_2$
2550.971	2 *H*	39189.0	$4d\,^1F_3-5p\,^3D^\circ_2$	2669.483	10 *h*	37449.3	$5p\,^1D^\circ_2-6s\,^3D_2$
2556.915	50 *h*	39097.9	$4d\,^1D_2-4f\,^1F^\circ_3$	2703.933	20 *H*	36972.2	$5p\,^3D^\circ_3-6s\,^3D_3$ $5p\,^3D^\circ_1-6s\,^3D_1$
2557.897	15 *h*	39082.9	$4d\,^3P_2-4f\,^3P^\circ_2$				
2569.812	10 *h*	38901.7	$4d\,^3D_3-5p\,^3F^\circ_4$	2716.594	20 *h*	36799.9	$4d\,^3S_1-5p\,^3P^\circ_2$
2570.724	80 *h*	38887.9	$4d\,^1G_4-4f\,^1H^\circ_5$	2718.722	2 *h*	36771.1	$5p\,^3D^\circ_2-6s\,^3D_2$
2584.636	40 *h*	38678.6	$4d\,^1D_2-4f\,^1D^\circ_2$	2727.780	1 *h*	36649.0	$5p\,^3D^\circ_2-6s\,^3D_1$
2587.258	10 *h*	38639.4	$4d\,^3D_2-5p\,^3F^\circ_3$	2740.545	5 *h*	36478.3	$4d\,^1P_1-5p\,^1D^\circ_2$
2592.747	( )	38557.6	$4d\,^3D_1-5p\,^3F^\circ_2$	2740.966	5 *h*	36472.7	$5p\,^3D^\circ_3-6s\,^3D_2$
2595.858	20 *H*	38511.4	$4d\,^1F_3-5p\,^1D^\circ_2$	2743.523	20 *h*	36438.7	$4d\,^3S_1-5p\,^3P^\circ_1$
2596.761	15 *h*	38498.0	$4d\,^3P_0-4f\,^3D^\circ_1$	2751.528	10 *h*	36332.7	$5p\,^3F^\circ_2-6s\,^3D_1$
2598.287	30 *h*	38475.4	$4d\,^3P_2-4f\,^3D^\circ_3$	2763.860	15 *h*	36170.6	$5p\,^3F^\circ_3-6s\,^3D_2$
2599.983	30 *h*	38450.3	$4d\,^3P_1-4f\,^3D^\circ_2$	2764.219	15 *h*	36165.9	$5p\,^3F^\circ_4-6s\,^3D_3$
2603.213	10 *h*	38402.6	$4d\,^3P_1-4f\,^3D^\circ_1$	2824.131	20 *h*	35398.7	$4d\,^1G_4-4f\,^1G^\circ_4$
2607.633	5 *h*	38337.5	$4d\,^3D_2-5p\,^3D^\circ_3$	2834.089	5 *H*	35274.3	$5p\,^3P^\circ_2-6s\,^3D_3$
2610.323	10 *h*	38298.0	$5p\,^1D^\circ_2-6s\,^1D_2$	2850.160	2 *H*	35075.4	$5p\,^1F^\circ_3-6s\,^1D_2$
2614.159	1 *h*	38241.8	$4d\,^3D_1-5p\,^3D^\circ_2$	2899.575	2 *h*	34477.7	$5p\,^1P^\circ_1-6s\,^1D_2$
2620.320	25 *h*	38151.9	$4d\,^3G_4-5p\,^3F^\circ_4$	3034.27	10	32947.3	$4d\,^3F_4-5p\,^3F^\circ_4$
2623.483	15 *h*	38105.9	$4d\,^3P_2-4f\,^1F^\circ_3$	3052.346	10	32752.16	$5p\,^1D^\circ_2-5d\,^1D_2$
2624.213	50 *h*	38095.3	$4d\,^3D_3-5p\,^3D^\circ_3$	3055.864	5	32714.46	$4d\,^3F_3-5p\,^3F^\circ_3$
2628.090	20 *h*	38039.1	$4d\,^3D_2-5p\,^3D^\circ_2$	3060.146	5	32668.68	$4d\,^3F_2-5p\,^3F^\circ_2$
2636.401	30 *h*	37919.2	$4d\,^3D_1-5p\,^3D^\circ_1$	3067.85	tr?	32586.6	$5p\,^3D^\circ_2-5d\,^3P_2$
2636.936	10 *h*	37911.5	$4d\,^3G_3-5p\,^3F^\circ_3$	3077.476	15	32484.72	$4d\,^1D_2-5p\,^1P^\circ_1$
2644.946	8 *h*	37796.7	$4d\,^3D_3-5p\,^3D^\circ_2$	3084.36	1	32412.2	$4d\,^3F_3-5p\,^3D^\circ_3$
2645.541	80 *H*	37788.2	$4d\,^3G_5-5p\,^3F^\circ_4$	3096.226	2	32288.01	$5p\,^3D^\circ_3-5d\,^3P_2$
				3110.416	30	32140.72	$4d\,^3F_4-5p\,^3D^\circ_3$

TABLE 3. *Classified lines of* V IV—Continued

λ air	Intensity	Wave number	Classification	λ air	Intensity	Wave number	Classification
3113.022	25	32113.81	$4d\,^3F_3-5p\,^3D^\circ_2$	3489.51	tr	28649.1	$4d\,^3P_2-5p\,^3D^\circ_3$
3121.304	10	32028.60	$4d\,^3F_2-5p\,^3D^\circ_1$	3490.913	30	28637.61	$5p\,^3F^\circ_2-5d\,^3G_3$
3135.192	20	31886.73	$4d\,^1D_2-5p\,^1F^\circ_3$	3496.419	50	28592.51	$5p\,^3F^\circ_3-5d\,^3G_4$
3227.507	15	30974.72	$5p\,^3D^\circ_1-5d\,^3F_2$	3500.57	1 *H*	28558.6	$5p\,^3P^\circ_0-5d\,^3S_1$
3229.92	tr	30951.6	$5p\,^3P^\circ_2-5d\,^3P_1$	3504.10	1 *H*	28529.8	$4d\,^3P_1-5p\,^3D^\circ_2$
3234.251	20	30910.14	$5p\,^3D^\circ_2-5d\,^3F_3$	3505.70	10	28516.8	$5p\,^3P^\circ_1-5d\,^3S_1$
3241.460	40 *H*	30841.40	$5p\,^3D^\circ_3-5d\,^3F_4$	3514.25	80 *h*	28447.4	$5p\,^3F^\circ_4-5d\,^3G_5$
3268.077	15 *h*	30590.22	$5p\,^3P^\circ_2-5d\,^3P_2$	3525.89	tr *H*	28353.5	$5p\,^3F^\circ_3-5d\,^3G_3$
3274.931	5 *H*	30526.20	$4d\,^3P_1-5p\,^3P^\circ_2$	3545.98	tr *h*	28192.9	$5p\,^3F^\circ_3-5d\,^3D_2$
3284.560	50	30436.71	$5p\,^1F^\circ_3-5d\,^1G_4$	3550.718	10	28155.27	$5p\,^3P^\circ_2-5d\,^3S_1$
3294.259	40	30347.10	$4d\,^3P_2-5p\,^3P^\circ_2$	3681.04	10	27158.5	$5p\,^3P^\circ_1-5d\,^3D_2$
3295.501	10	30335.66	$5p\,^3F^\circ_2-5d\,^3F_2$	3691.236	15	27083.46	$5p\,^3P^\circ_2-5d\,^3D_3$
3298.371	20	30309.27	$5p\,^3F^\circ_3-5d\,^3F_3$	3833.74	15 *H*	26076.8	$5p\,^1P^\circ_1-5d\,^1P_1$
3303.719	5	30260.21	$4d\,^3P_0-5p\,^3P^\circ_1$	4136.72	5 *H*	24166.9	$4d\,^1S_0-5p\,^1P^\circ_1$
3314.175	2	30164.74	$4d\,^3P_1-5p\,^3P^\circ_1$	4450.75	tr	22461.8	$4f\,^3D^\circ_3-5d\,^3P_2$
3318.788	5 *h*	30122.82	$4d\,^3P_1-5p\,^3P^\circ_0$	4479.195	2 *h*	22319.18	$4f\,^1F^\circ_3-5d\,^1D_2$
3328.527	30	30034.68	$5p\,^3F^\circ_4-5d\,^3F_4$	4505.17	1 *H*	22190.5	$4f\,^3F^\circ_3-5d\,^3F_2$
3333.986	15	29985.50	$4d\,^3P_2-5p\,^3P^\circ_1$	4508.67	2 *H*	22173.3	$4f\,^3F^\circ_4-5d\,^3F_4$
3334.79	60	29978.3	$4d\,^1G_4-5p\,^1F^\circ_3$	4518.58	8 *H*	22124.6	$4f\,^3H^\circ_5-5d\,^3F_4$
3385.336	1	29530.69	$5p\,^1F^\circ_3-5d\,^1D_2$	4565.63	tr *H*	21896.6	$4f\,^3G^\circ_3-5d\,^3F_2$
3433.52	tr	29116.3	$5p\,^3D^\circ_1-5d\,^3D_2$	4608.15	1 *H*	21694.6	$4f\,^3G^\circ_5-5d\,^3F_4$
3448.410	50	28990.57	$5p\,^1D^\circ_2-5d\,^1F_3$	4616.57	1 *H*	21655.0	$4f\,^3G^\circ_4-5d\,^3F_3$
3452.741	3 *H*	28954.20	$5p\,^3D^\circ_2-5d\,^3G_3$	4643.985	10 *H*	21527.20	$4f\,^1H^\circ_5-5d\,^1G_4$
3455.325	15	28932.55	$5p\,^1P^\circ_1-5d\,^1D_2$	4801.54	2 *H*	20820.8	$5s\,^3D_2-5p\,^3P^\circ_2$
3459.40	10 *h*	28898.5	$5p\,^3D^\circ_1-5d\,^3D_1$	4828.990	1 *H*	20702.48	$4d\,^1S_0-5p\,^3D^\circ_1$
3471.989	20	28793.69	$5p\,^3D^\circ_2-5d\,^3D_2$	4841.26	20 *h*	20650.0	$5s\,^1D_2-5p\,^1P^\circ_1$
3473.458	20	28781.51	$5p\,^3D^\circ_3-5d\,^3D_3$	4845.21	3 *h*	20633.2	$5s\,^3D_1-5p\,^3P^\circ_1$
3487.63	30	28664.6	$4d\,^1D_2-5p\,^1D^\circ_2$	4855.05	3 *H*	20591.3	$5s\,^3D_1-5p\,^3P^\circ_0$

TABLE 3. *Classified lines of* V IV—Continued

λ air	Intensity	Wave number	Classification	λ air	Intensity	Wave number	Classification
4886.36	20 *h*	20459.4	$5s\ ^3D_2-5p\ ^3P^\circ_1$	5175.950	30 *h*	19314.75	$5s\ ^3D_1-5p\ ^3F^\circ_2$
4891.52	tr *h*	20437.8	$4f\ ^3G_3-5d\ ^3G^\circ_4$	5222.93	5 *H*	19141.0	$5s\ ^3D_2-5p\ ^3F^\circ_2$
4899.56	tr *h*	20404.3	$4f\ ^3H^\circ_4-5d\ ^3D_3$	5227.89	10 *H*	19122.8	$5s\ ^3D_2-5p\ ^3D^\circ_2$
4906.280	40 *h*	20376.35	$5s\ ^3D_3-5p\ ^3P^\circ_2$	5262.164	50 *h*	18998.3	$5s\ ^3D_1-5p\ ^3D^\circ_2$
4913.083	10 *h*	20348.14	$4f\ ^1G^\circ_4-5d\ ^1F_3$	5267.045	10 *h*	18980.69	$5s\ ^3D_3-5p\ ^3F^\circ_3$
4916.94	2 *H*	20332.2	$4f\ ^3F^\circ_3-5d\ ^3D_2$	5310.77	20 *H*	18824.4	$5s\ ^3D_2-5p\ ^3D^\circ_2$
4954.408	1 *h*	20178.41	$4f\ ^3H^\circ_5-5d\ ^3G_4$	5352.320	60 *h*	18678.29	$5s\ ^3D_3-5p\ ^3D^\circ_3$
4966.38	2 *h*	20129.8	$4f\ ^3G^\circ_3-5d\ ^3F_2$	5353.090	25 *H*	18675.60	$5s\ ^3D_1-5p\ ^3D^\circ_1$
4970.348	3 *h*	20113.70	$4f\ ^3F^\circ_4-5d\ ^3D_3$	5387.210	3 *h*	18557.32	$4f\ ^1F^\circ_3-5d\ ^1F_3$
4971.941	1 *h*	20107.26	$4f\ ^3G^\circ_5-5d\ ^3G_5$	5496.67	1 *H*	18187.8	$4f\ ^3D^\circ_3-5d\ ^1F_3$
4985.653	50 *h*	20051.96	$5s\ ^1D_2-5p\ ^1F^\circ_3$	5509.19	30 *H*	18146.4	$5s\ ^3D_2-5p\ ^1D^\circ_2$
5035.460	10 *h*	19853.62	$4f\ ^3H^\circ_6-5d\ ^3G_5$	5520.63	2 *H*	18108.9	$5s\ ^1D_2-5p\ ^3F^\circ_3$
5074.90	5 *H*	19699.3	$4f\ ^3G^\circ_4-5d\ ^3G_3$	5608.71	20 *H*	17824.4	$5s\ ^1D_2-5p\ ^3F^\circ_2$
5130.78	50 *H*	19484.8	$5s\ ^3D_3-5p\ ^3F^\circ_4$	5710.10	8 *H*	17508.0	$5s\ ^1D_2-5p\ ^3D^\circ_2$
5146.502	40 *h*	19425.26	$5s\ ^3D_2-5p\ ^3F^\circ_3$	5940.12	40 *H*	16830.0	$5s\ ^1D_2-5p\ ^1D^\circ_2$

TABLE 4. *Energy levels and limits of the* ns *series of* V IV

Electron	Desig.	Energy level	Term value	n^*	Limit	I.P.
4*s*	$^3D_3$	96798.0	280538.0	2.50172		
5*s*	$^3D_3$	236766.9	140569.1	3.53419	377336	376716
6*s*	$^3D_3$	292417.4	84918.6	4.54709		
4*s*	$^3D_2$	96412.1	280353.9	2.50254		
5*s*	$^3D_2$	236322.4	140443.6	3.53577	376766	376766
6*s*	$^3D_2$	291918.1	84847.9	4.54898		
4*s*	$^3D_1$	96196.1	280515.9	2.50182		
5*s*	$^3D_1$	236148.6	140563.6	3.53426	376712	376712
6*s*	$^3D_1$	291796.0	84916.0	4.54716		
4*s*	$^1D_2$	100200.7	277134.3	2.51704		
5*s*	$^1D_2$	237638.8	139696.2	3.54522	377335	376715
6*s*	$^1D_2$	292766.7	84568.3	4.55651		

4. V v

As a by-product of the V IV analysis, 8 lines of the fifth spectrum of vanadium were identified in the region 675 to 2200 Å. With the present measurements, the levels published in A.E.L. [2] giving combinations in this part of the spectrum have been corrected and the ^{2}D term of the $4d$ configuration has been found. The new values based on the assumption that $4p^2\ P^\circ_{1\frac{1}{2}} = 207617.0\ cm^{-1}$ is correct, are the following:

New levels of V v

Config.	Desig.	J	Level
$4s$	^2S	$0\frac{1}{2}$	148100.1
$4p$	$^2P^\circ$	$0\frac{1}{2}$	206350.6
$4d$	^2D	$1\frac{1}{2}$	293859.5
		$2\frac{1}{2}$	294004.3
$5s$	^2S	$0\frac{1}{2}$	328173.5
$4f$	$^2F^\circ$	$3\frac{1}{2}$	349210.6

the observed combinations among them are as follows:

Newly classified lines of V v

λ	Int.	Wave number	Classification
820.866	15	121822.5	$4p\ ^2P^\circ_{0\frac{1}{2}} - 5s\ ^2S_{0\frac{1}{2}}$
829.483	20	120557.0	$4p\ ^2P^\circ_{1\frac{1}{2}} - 5s\ ^2S_{0\frac{1}{2}}$
1142.741	40	87508.9	$4p\ ^2P^\circ_{0\frac{1}{2}} - 4d\ ^2D_{1\frac{1}{2}}$
1157.577	50	86387.3	$4p\ ^2P^\circ_{1\frac{1}{2}} - 4d\ ^2D_{2\frac{1}{2}}$
1159.520	10	86242.6	$4p\ ^2P^\circ_{1\frac{1}{2}} - 4d\ ^2D_{1\frac{1}{2}}$
1680.199	100	59516.9	$4s\ ^2S_{0\frac{1}{2}} - 4p\ ^2P^\circ_{1\frac{1}{2}}$
1716.722	50	58250.5	$4s\ ^2S_{0\frac{1}{2}} - 4p\ ^2P^\circ_{0\frac{1}{2}}$
1811.388	40 *h*	55206.3	$4d\ ^2D_{2\frac{1}{2}} - 4f\ ^2F^\circ_{3\frac{1}{2}}$

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